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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2003905705 for a patent by VICIOUS POWER PTY LTD as filed on 17 October 2003.

WITNESS my hand this
Twenty-sixth day of October 2004

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SUPPORT AND SALES

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Regulation 3.2

AUSTRALIA

Patents Act 1990

ORIGINAL

PROVISIONAL SPECIFICATION FOR AN INVENTION ENTITLED

Invention Title: ELECTRONIC POWER CONTROL FOR LAMPS

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The invention is described in the following statement :

This invention relates to a method of providing electrical power for portable lighting systems and is also directed to a controller and an installation where a battery power source is used with portable lighting systems that require controlled DC power that is continuous such as metal halide arc lamps and light emitting diodes.

A disadvantage with prior art devices is that they allow light output, which is highly sensitive to the available voltage, to vary as a battery supply passes through charge states. This can be highly disadvantageous in situations where the extent of light available is very important. US Patent Number 5291900 discloses a more sophisticated low watt metal halide lamp apparatus. It utilizes a DC voltage regulator (boost topology) to turn the range of 6-15VDC into a steady 15VDC. This controlled voltage is then used to deliver electrical current to an arc lamp via a flyback transformer with rectified output.

An object of this invention is to provide a power controller that can operate lighting systems that require controlled DC power that is continuous, such as arc lamps and LED's, using a regulation technique which is efficient both from a point of view of power usage, therefore enabling longer use from a battery charge; and from a manufacturing cost point of view.

In one form of the invention, although it may not be the only or indeed the broadest form, the invention may be said to reside in a method of effecting a supply of electrical power to an electrical-to-light output transducer where the input from a direct current supply is directed into a means which will effect transition into an output wherein said means further includes means to effect frequent switching wherein the mark-space ratio of the switching is able to be modified such that the input power is held effectively constant. In an alternative form the invention can be said to reside in an apparatus adapted to perform this method.

In a further form the invention can be said to reside in an assembly with an apparatus as described coupled to an electric-to-light output transducer.

In preference the transducer is an arc lamp.

In the alternative the transducer is one or more light emitting diodes.

In preference in the alternative the invention includes a power controller for use with high performance portable lighting systems including a DC voltage source, a transformer including a primary and a secondary coil, a switch means adapted to control application of the source voltage to the primary coil of said transformer, means adapted to control the operation of the switch, and means adapted to

determine a required duty cycle for the switch such that the level of power delivered to the primary coil is substantially constant, said power controller being adapted to provide a substantially constant power throughput.

In preference, the means adapted to determine the duty cycle of a switch includes means to sense the magnitude of a voltage being provided by the voltage source. This allows the battery voltage, which varies according to its discharge cycle, to be monitored and not to affect the output as such being supplied to the electric-to-light transducer.

In preference, the means to calculate the duty cycle of the switch calculates this duty cycle according to the fixed mathematical relationship between said duty cycle and input voltage the inductance of the coil and a desired power throughput of the device

In preference, the means adapted to determine the duty cycle of the switch includes a microprocessor.

In preference, the means to calculate the duty cycle of the switch include stored instructions adapted to be followed by the microprocessor.

In preference, there is a rectifier circuit connected to the secondary coil.

In preference, the voltage source is unregulated. This voltage source may be a battery.

The use of the a regulator to feed a constant DC input to the power transformer allows system stability with the use of more than one battery combination. However, the need for the DC regulator detracts from the electrical efficiency of the ballast, increases physical size of the circuitry, and adds parts to the bill of materials increasing cost and decreasing reliability.

LEDs typically operate in response to a specified level of current flow but have a characteristic voltage drop across the diode associated with their normal running power. Although they require a controlled amount of current flow for proper function, they do not normally offer any inherent current limiting capacity.

The cheapest and simplest method of current control in the prior art is to use a "fixed" voltage power source, in series with a LED array and a current limiting resistor.

A disadvantage of this apparatus is that the current limiting resistor dissipates a significant percentage of the total power, leading to poor over-all efficiency. Also, as battery voltage drops, current in the circuit will also drop, leading to a significant loss of light output from the LED.

A better approach is to use a current regulated driver, employing a resistor in series with the LED array acting as a current sense resistor to provide a feedback signal to a pulse width modulation controller to ensure constant current flow through the LED array.

The current regulated driver offers constant brightness of LEDs even as input voltage falls over time (e.g. a discharging battery). A disadvantage is the power dissipated in the current sensing resistor. The current sense resistor can be of low ohmic value to reduce this loss, however, low ohm resistors of precise value are more expensive than more commonly available components.

For a better understanding of this invention, it will now be described with respect to the prior art and to a preferred embodiment which shall be described herein with the assistance of drawings wherein;

Figure 1 is a circuit diagram of a ballast of the prior art adapted for use with an arc lamp;

Figure 2 is a circuit diagram of a power controller of the prior art including an independent regulator for the DC voltage;

Figure 3 is a circuit diagram of an LED drive circuit of the prior art using a current limiting resistor;

Figure 4 is a LED driver of the prior art employing current regulation;

Figure 5 is a circuit diagram of a preferred embodiment of the present invention;

Figure 6 is a more detailed circuit diagram of a preferred embodiment of the present invention showing it adapted for use with an arc lamp circuit;

Figure 7 is a listing of the assembly language code stored in the microprocessor to effect the calculation of the switch period.

Figure 1 shows a circuit diagram of a simple commercially available arc lamp apparatus. Arc lamps typically require a voltage pulse of around 6,000 volts to strike the arc and then typically 50-100 volts to continue running.

In portable applications, Power supply circuitry is required in order to produce these voltages from a battery. Figure 1 shows a circuit for such a power supply in the form of a simple flyback DC-DC converter. This consists of a battery 1 providing voltage to the primary coil 2 of a transformer 3 and a switch 5 under the control of an oscillator 6. The high voltage output is drawn from the secondary coil 4 of the transformer via a rectifier circuit consisting of diode 7 and capacitor 8. The

6,000 volt pulse required to strike the arc of the lamp 9 is provided by the trigger circuit 10.

The main disadvantage of the simple circuit of figure 1 is that it employs no regulation and therefore power delivery varies with input voltage. The unregulated power supply can only be used with a limited range of battery combinations with narrow voltage specifications.

Figure 2 shows a prior art power supply for an arc lamp similar to that of figure 1 but with the addition of a DC voltage regulator 11. This fixes the input voltage applied to the primary coil 2 of the transformer 3 at a value of 15 volts. This allows for stable operation over a wider range of input voltages from 6-15 volts but it does this at the expense of additional circuitry and a reduction in the efficiency of operation of the circuit.

Figure 3 shows a prior art implementation of a LED drive incorporating a current limiting resistance. LED 30 has a characteristic voltage drop of 3 volts and a characteristic operating current of 350 milliamps. When driven from a 6 volt DC source 31 it is necessary to provide a resistor to limit the current flowing through the diode to a value approximating its rate at current capacity. In this case, the voltage drop across the resistor 32 will be 3 volts and to achieve a current of 360 milliamps a value for the resistor of 8.2 ohms is chosen.

This circuit provides appropriate current drive to the LED but at the expense of very poor efficiency since a significant percentage of the total power is dissipated in the current limiting resister. Also the current is unregulated meaning that it will vary with the varying voltage of the battery 31 during its discharge cycle and the output of the LED will vary accordingly.

Figure 4 shows a current regulated LED driver circuit. A battery 40 supplies power to a power supply consisting of inductor 41, MOSFET switch 42 and pulse wave modulation (PWM) controller 43. The period of the switch is set by the PWM controller in order to maintain the voltage across the current sensing resistor 44 at a substantially constant level. Hence the current flowing through the LED chain 45 is maintained substantially constant.

Figure 5 is a circuit diagram of a lamp power supply according to an embodiment of the present invention. The power source to the power controller is a battery 50 which may be one of a variety of voltage levels and need not provide a fixed voltage input. There is a microcontroller chip 51 which has a voltage sensing input 52 and an output 53 which controls a switch in the form of a MOSFET transistor 54. This switch controls the supply of power to a primary coil 55 of a transformer 56.

This transformer has a secondary coil 57 to which is connected a rectifier circuit consisting of diode 58 and capacitor 59. The load on the circuit 60 may be an arc lamp including an arc lamp trigger circuit or an LED or an array of LEDs.

The controller of this embodiment achieves power regulation based on the principle that energy stored in the primary inductance of the transformer is V^2t^2/L where V represents input voltage, t is the period of the primary switch and L is the inductance of the primary coil of the transformer. Accordingly, the output power is proportional to V^2d^2/L where d is the duty cycle of the switch. The inductance has a constant value, hence this fixed mathematical relationship allows the appropriate duty cycle to be determined to ensure a required constant power level.

The microcontroller 51 samples the input voltage. The value of the inductance of the primary coil of the power transformer is supplied to the microcontroller as a constant value during set up. The microcontroller includes stored instructions which are shown as figure 7 allowing it to calculate the duty cycle of the switch according to the above formula such that there is always a constant power being delivered from the battery to the primary coil of the transformer and accordingly into the load. This system avoids the need for separate DC voltage regulator or for a current limiting or current sensing resister. Accordingly, the embodiment of the invention is both more efficient and cheaper to manufacture than devices of the prior art.

Throughout this specification the purpose has been to illustrate the invention and not to limit this.

Dated this 17th day of October 2003

VICIOUS POWER PTY LTD

By their Patent Attorneys

COLLISON & CO

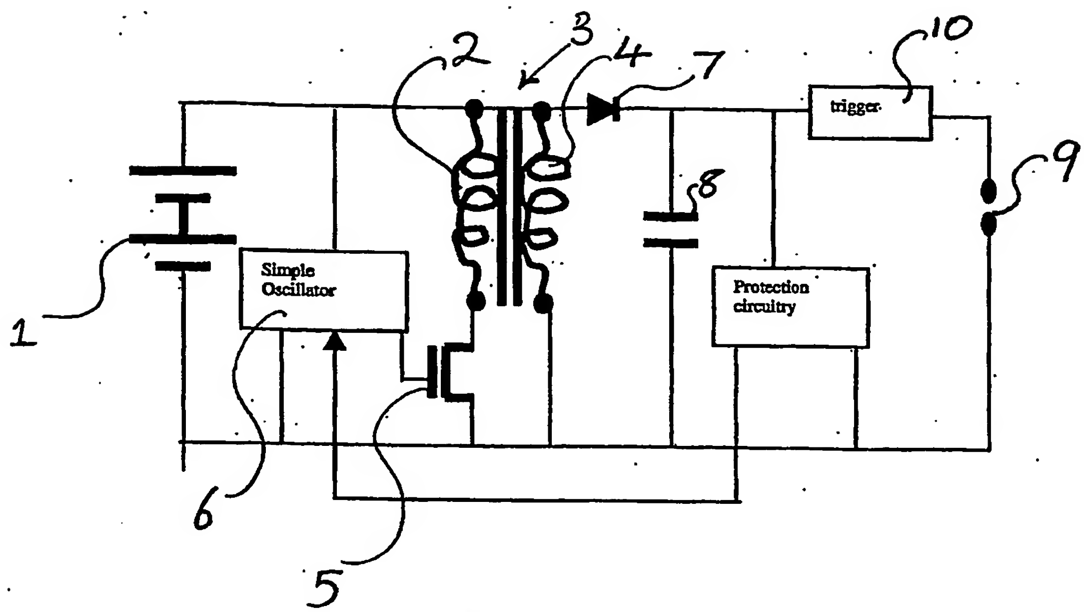

Figure 1

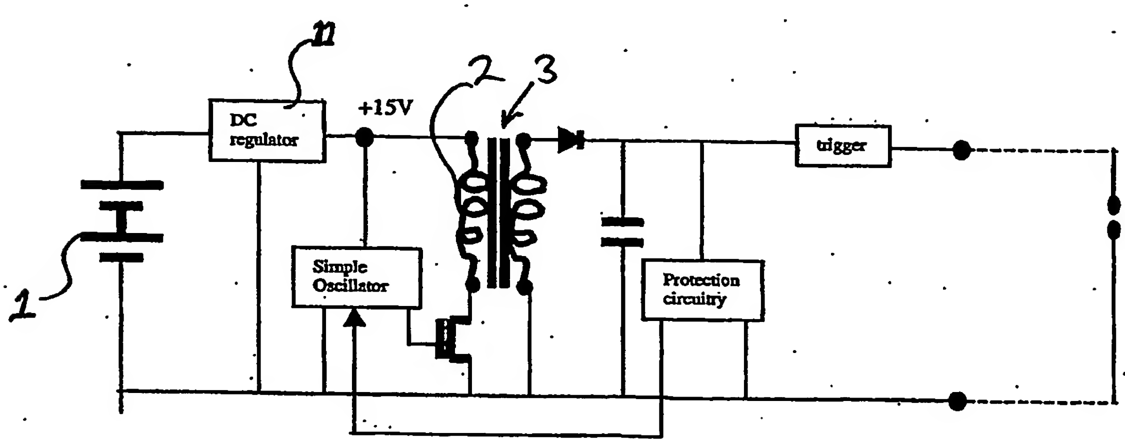

Figure 2

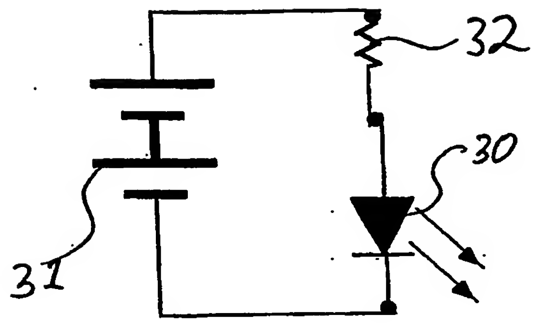

Figure 3

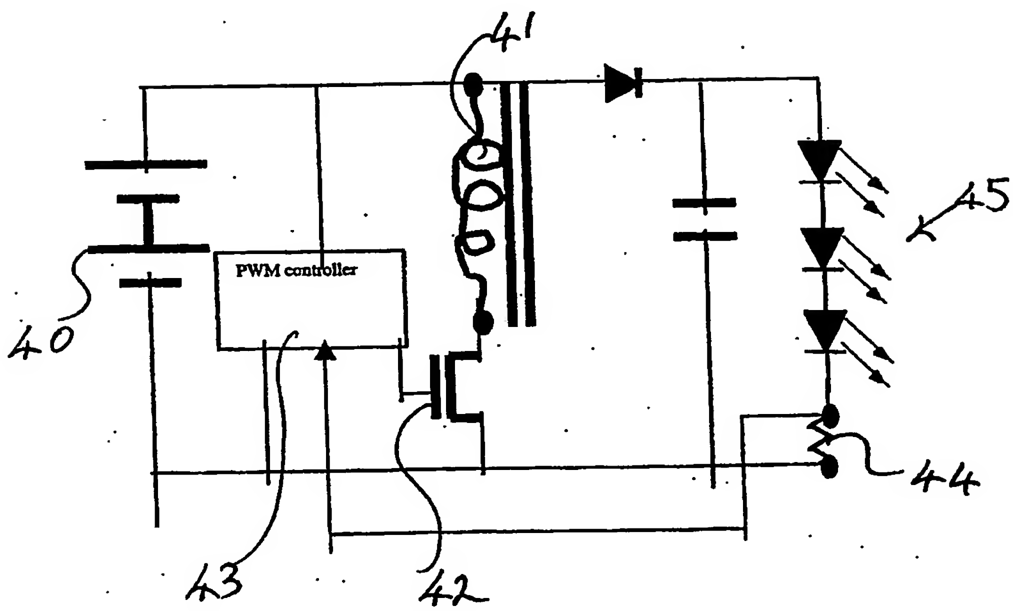

Figure 4

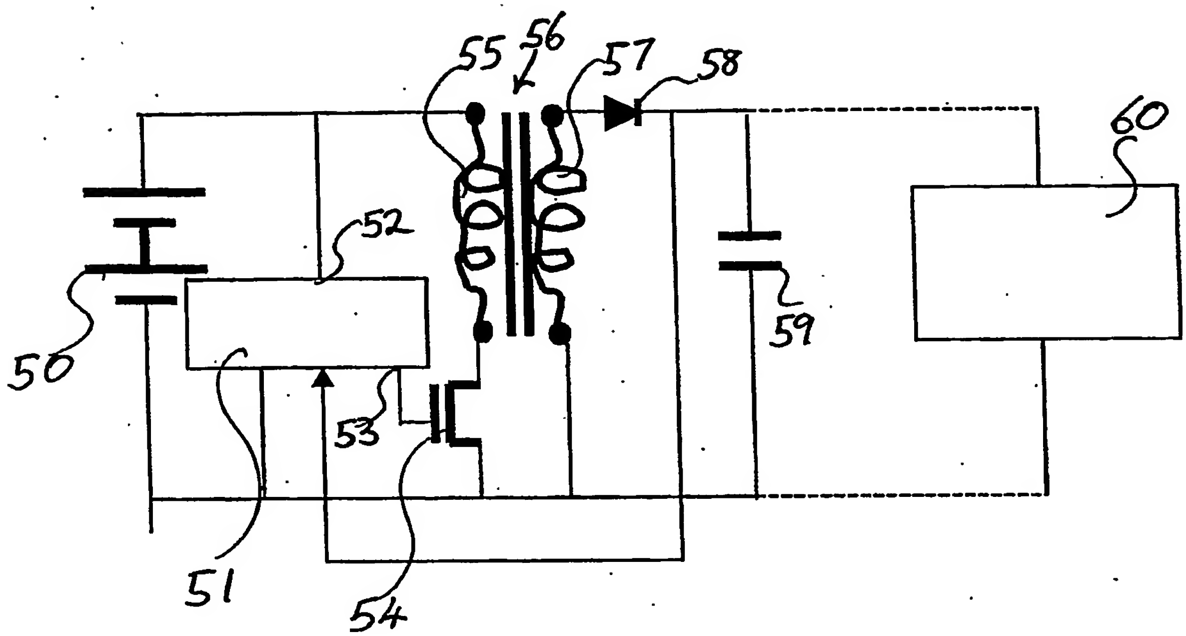

Figure 5

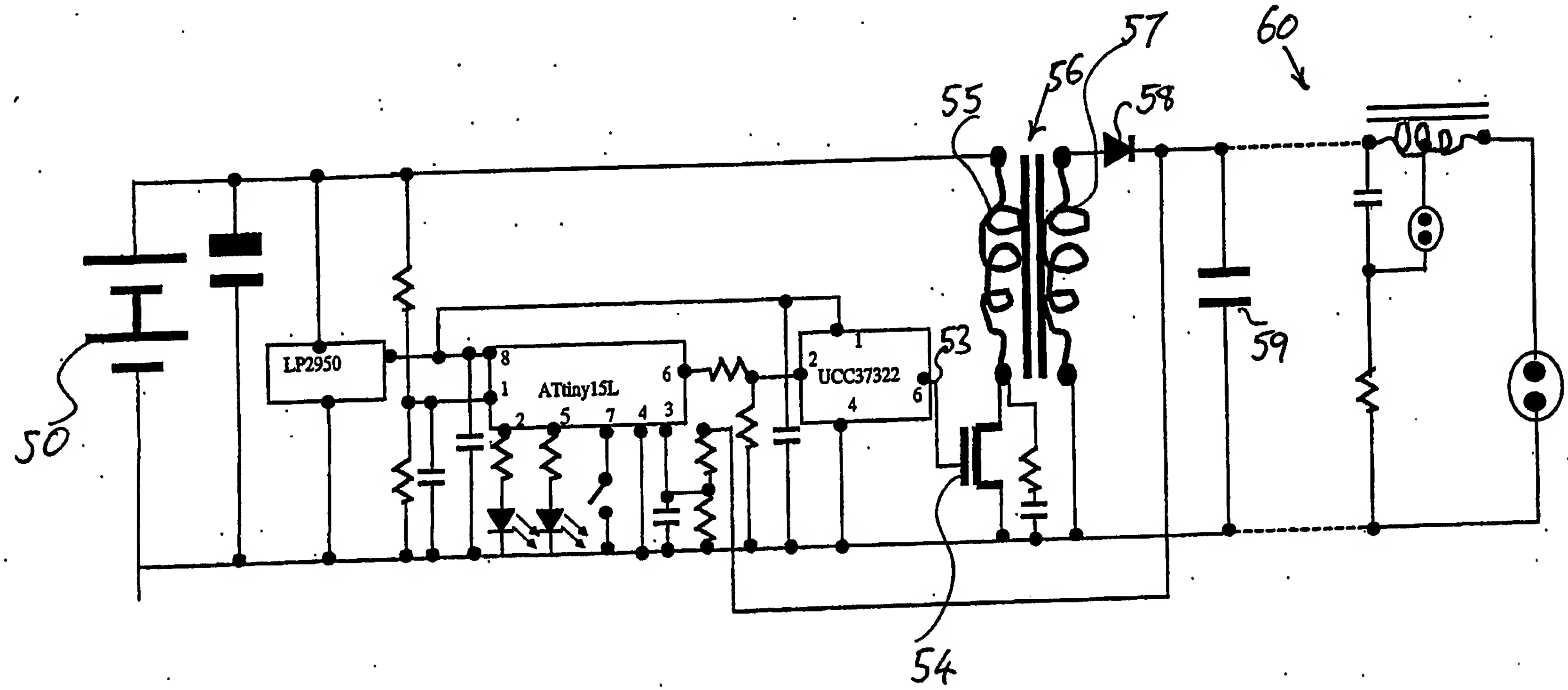

Figure 6

FIG.7

```
RJMP    +0x0118
RJMP    +0x0100
NOP
NOP
NOP
RJMP    +0x0101
NOP
NOP
RJMP    +0x0160

; look-up table inserted here

; Look-up routine
SUBI    R17,0x6C
SBCI    R18,0x01
BRCS    +0x0E
BST     R29,5
BRTS    +0x03
LDI     R30,0x12
LDI     R31,0x00
RJMP    +0x0005
SUBI    R18,0x01
LSR     R18
ROR     R17
LDI     R30,0x12
LDI     R31,0x01
ADD     R30,R17
ADC     R31,R18

; Fetch duty cycle from table
LPM
RET
CLR     R0
RET
RJMP    +0x0019
IN      R5,0x3F
CLR     R6
OUT     0x3B,R6
OUT     0x3F,R5
RETI

IN      R5,0x3F
INC     R23
DEC     R19
DEC     R22
IN      R9,0x16
BST     R9,2
```

FIG. 7

```
BRTC    +0x09
CPI     R21,0x31
BRCC    +0x02
ORI     R29,0x04
RJMP    +0x0004
CPI     R21,0x45
BRCC    +0x02
ANDI    R29,0xFB
RJMP    +0x0000
LDI     R21,0x49
DEC     R21
RJMP    -0x0014
CLI
RCALL   +0x00AE
ANDI    R29,0x10
CLR     R20
OUT     0x2E,R20
SBI     0x18,4
CBI     0x18,0
SEI
LDI     R19,0x48
AND     R19,R19
BRNE    -0x02
CLI
LDI     R16,0x40
OUT     0x3B,R16
CBI     0x18,4
SEI
SLEEP
CLI
BST     R29,4
BRTS    -0x12
LDI     R29,0x03
CLR     R3
CLR     R17
CLR     R18
CLR     R4
CLR     R28
SEI
LDI     R16,0x80
OUT     0x7,R16
SBI     0x6,6
LDI     R22,0x78
LDI     R21,0x48
RCALL   +0x0006
AND     R21,R21
BREQ    -0x21
AND     R22,R22
```

FIG. 7

```
BRNE    -0x05
ANDI    R29,0xFD
RJMP    -0x0007
SBRS    R29,0
RJMP    +0x0007
SBRC    R29,6
RJMP    +0x0011
SBRC    R29,3
RJMP    +0x0012
SBRC    R29,2
RJMP    +0x0016
RJMP    +0x0003
SBI     0x18,4
CBI     0x18,0
RET
SBI     0x18,0
CBI     0x18,4
RET
SBI     0x18,0
SBI     0x18,4
RET
CBI     0x18,0
CBI     0x18,4
RET
SBRS    R23,0
RJMP    -0x000B
RJMP    -0x0006
ANDI    R23,0x1F
CPI     R23,0x1E
BRCC    -0x0C
CP      R23,R24
BRCC    -0x0E
RJMP    -0x0012
SBRS    R23,4
RJMP    -0x0014
RJMP    -0x000F

; Read in battery voltage from ADC
IN      R26,0x4
IN      R27,0x5

SBI     0x7,1
SBI     0x6,6
ADD     R17,R26
ADC     R18,R27
RJMP    -0x0063
RJMP    -0x004E
IN      R5,0x3F
```

FIG. 7

```
SBIS    0x7,1
RJMP    -0x000B
IN      R26,0x4
IN      R27,0x5
CBI     0x7,1
SBI     0x6,6
ADD     R4,R26
ADC     R28,R27
INC     R3
SBRS    R3,6
RJMP    -0x0070
CLR     R3
BST     R29,0
BRTS    +0x03
CLR     R18
CLR     R17
RJMP    +0x0049
MOV     R8,R18
ANDI    R29,0xBF
CPI     R28,0x46
BRCS    +0x03
ORI     R29,0x40
SBRS    R29,1
RJMP    -0x0067
CPI     R18,0xFF
BRCC    -0x1C
CPI     R18,0x9B
BRCS    +0x02
ORI     R29,0x20
RJMP    +0x0005
ANDI    R29,0xDF
CPI     R18,0x64
BRCS    +0x02
ORI     R29,0x10
RJMP    -0x0072
BST     R29,1
BRTS    +0x13
MOV     R24,R18
SUBI    R24,0x64
ADD     R24,R24
ADD     R24,R24
LSR     R24
BST     R29,3
BRTS    +0x0C
CPI     R18,0x78
BRCC    +0x09
INC     R10
BST     R10,7
```

FIG. 7

```
BRTC    +0x07
ORI     R29,0x08
MOV     R16,R0
LSR     R16
LSR     R16
SUB     R0,R16
MOV     R7,R0
CLR     R10
ANDI    R17,0xC0
ADD     R17,R17
ADC     R18,R18
ADC     R17,R17
ADC     R18,R18
ADC     R17,R17
MOV     R16,R18
MOV     R18,R17
MOV     R17,R16
RCALL   -0x00BE
BST     R29,3
BRTS    +0x02
BST     R29,2
BRTC    +0x07
MOV     R16,R0
LSR     R16
LSR     R16
SUB     R0,R16
CP      R7,R0
BRCS    +0x01
MOV     R7,R0
CP      R20,R0
BREQ    +0x02
BRCS    +0x04
BRCC    +0x07
SBRC    R29,3
MOV     R20,R7
RJMP    +0x0005
INC     R20
SBRC    R29,3
MOV     R20,R7
RJMP    +0x0001
MOV     R20,R0
OUT     0x2E,R20
CLR     R17
CLR     R18
CLR     R4
CLR     R28
RJMP    -0x00C4
IN      R16,0x34
```

```
SBRC    R16,0
CLR     R29
LDI     R16,0x30
OUT     0x35,R16
LDI     R16,0x13
OUT     0x17,R16
SBI     0x18,2
SBI     0x18,4
LDI     R16,0x10
OUT     0x21,R16
LDI     R16,0x00
OUT     0x21,R16
LDI     R30,0xFF
LDI     R31,0x03
LPM
OUT     0x31,R0
CLR     R0
LDI     R16,0x8B
OUT     0x6,R16
LDI     R16,0x61
OUT     0x30,R16
LDI     R16,0xFF
OUT     0x2D,R16
LDI     R16,0x04
OUT     0x33,R16
LDI     R16,0x02
OUT     0x39,R16
LDI     R16,0x60
OUT     0x3A,R16
CLR     R16
OUT     0x34,R16
RET
```

Figure 7

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